FEASIBILITY OF RAINWATER HARVESTING IN NORTH GEORGIA'S HUMID CLIMATE

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Abstract. With the growing implementation of active rainwater harvesting systems in large scale building projects in the southesast, the question of what value these systems provide in a humid climate is raised. A water budget model has been developed to provide an analysis of water supply and demand for a sample design site located in northern Georgia. Using historical precipitation and potential evapotranspiration data for two years (a wet year and a dry year), along with the catchment area, irrigation area and soil type of the design site, the value provided by an active rainwater harvesting system with cistern storage in the temperate southeast can be evaluated. The model generated in the form of spreadsheets and charts, demonstrates the limits of the physical feasibility of such a system.

PURPOSE AND TIMELINESS

There appears to be a collective assumption that there are environmental benefits to be gained, not only in arid environments but in the humid climate of the southeast, through the practice of harvesting and storing rainwater for future use. Environmental responsibility in water conservation is the apparent impetus for incorporating cisterns to supply landscape irrigation, however research based on regional weather data to support this practice in humid climates seems lacking. Several southeastern university campuses have incorporated cisterns in recent construction projects. Examples can be found at the University of North Carolina - Chapel Hill, the University of Florida, the University of Georgia and Emory University. In research for the current study, no sources of data collection to determine the benefits of the installed water harvesting systems were found at these institutions.

This paper attempts to make a contribution toward answering the question whether cisterns are, in fact, physically feasible in the humid climate of northern Georgia. Through the use of water budget modeling on a sample design site, rainwater storage in cisterns for use in landscape irrigation systems will be studied to determine the water conservation advantages. More specifically, this paper attempts to answer the questions, to what degree can rainwater harvesting supply irrigation water in Georgia, and what design factors can be manipulated to make it optimally feasible on a specific site.

Approach

Examples of questions which can be raised regarding cistern use in the humid climate of the Southeast are: 1) Is rainfall plentiful enough that no additional irrigation is required? 2) When is it practical to make a water harvesting system 'active' by adding a cistern? How much storage is needed? 3) If irrigation is required only for plant establishment, does it make sense to install cisterns for the long term? 4) Must planting designs be adjusted to accommodate available quantities of harvested water? 5) Should cisterns serve the dual purpose of irrigation and stormwater detention? 6) For a given irrigated landscape planting area, what is the optimal catchment area to achieve valuable water conservation?

This paper does not attempt the scope of a water balance study, but rather that of a water budget. A water budget can provide a supply and demand analysis for a given inflow and projected outflow requirement, showing whether there is a need for supplemental water.

Method of Modeling Study

The sample design site used for this study was the proposed addition to the Georgia Museum of Art on the campus of The University of Georgia in Athens, Georgia, along with an adjacent landscaped site. The proposed pitched roof area of the museum addition served as the catchment area for harvesting rainwater and the adjacent landscaped area to the south of the addition served as the irrigation area represented in this study.

To begin a water budget model for a rainwater harvesting system, a specific catchment area must be identified and irrigation requirements must be determined based on planting area, planting type and other environmental factors. Given the catchment area, irrigation area and soil type of the design site, along with the daily precipitation and evapotranspiration data for two different years, one wet, one dry, a water budget model can illustrate the value provided by a rainwater harvesting system with cistern storage. The quantities resulting from the water budget analysis can be a basis for design proposals.

Daily rainfall data for two different years, one wet, one dry, were chosen for this modeling study. Whereas the average amount of precipitation in the Athens area per year is 49"(Hoogenboom et al.), the year 2000 had significantly lower than average rainfall at a total of 33.77" (dry year), and the year 2003 had higher than average precipitation at 60.9" (wet year). Two spreadsheet models were created: one to determine the irrigation requirement of the site, and another to track the irrigation supply provided by an active rainwater harvesting system.

Spreadsheet I: Irrigation Requirement

The Irrigation Requirement spreadsheet contributes to determining the value of an active rainwater harvesting system by studying the characteristics of the soil and plantings on the sample site. Factors employed to determine irrigation requirement included the SCS Curve Number runoff estimation method, planting area, landscape coefficient (KL), historical data for daily precipitation and evapotranspiration to arrive at the quantity for total water to be applied. (Available upon request.)

Spreadsheet II: Irrigation Water Supply

The Irrigation Water Supply spreadsheet tracks the harvested rainwater from roof catchment to cistern through irrigation use and calculates quantities of overflow or supplemental water required. The Roof Catchment Area of the sample site used in this study is 15,480 square feet, however variable catchment areas and cistern sizes were looked at in the course of this study. The Rational formula is used to estimate roof runoff, because Rational runoff coefficients are available, specifically for long-term average runoff from impervious surfaces, during both small and largestorms. A runoff coefficient with a value less than 1.0 must be applied to account for water loss resulting from, for instance, ponding in surface depressions or evaporation.values for the Rational coefficient as related to surface type, show a range of 0.75-1.00 for roofs (American Society of Plumbing Engineers). Heather Kinkade-Levario states in her recent book Forgotten Rain that "a maximum of 90 percent of a rainfall can be effectively captured through rooftop rainwater harvesting. For the current study, assuming either a built-up roof or asphalt shingles for the sample design site of the Georgia Museum of Art Addition, a constant coefficient of 0.90 was used based on Kinkade-Levario's recommendation. (Available upon request)

Results derived from Spreadsheet I

The difference in irrigation requirement between a wet and dry year was dramatically illustrated in the results of Spreadsheet I. All four of the landscape coefficients (KL) used were run for both years. The four different Landscape coefficients (KL) included KL 0.22: mixed plantings – low conditions, KL 0.55: mixed plantings – average conditions, KL 0.7: turfgrass – average conditions and KL 0.9: turfgrass – high conditions. The following table shows the resultant quantities of Total Water to be Applied (TWA) to the landsape plantings in gallons per year for each of the four landscape coefficients. TWA represents the total supplemental water needed by plantings from any source.

Table 1. Irrigation Requiirement Results (Total Water to be Applied, gallons) with varying Landscape coefficients (KL)

	KL 0.22 (gals.)	KL 0.55 (gals.)	KL 0.7 (gals.)	KL 0.9 (gals.)
2000 TWA	72,296	180,741	230,128	296,062
2003 TWA	560	1,480	1,939	2,580

Results derived from Spreadsheet II.

Charting the total quantities of Overflow and Supplemental water required derived from Spreadsheet II across a variable range of cistern volumes (varying in size from 10,000 to 150,000 gallons) provides a means of determining if a cistern provides a benefit and, if so, the minimum cistern size needed to maximize use of harvested rainwater. For example, in the dry year, 2000, if the given design site were planted with mixed plantings requiring average conditions (KL 0.55), a 60,000 gallon cistern could meet all irrigation demand with no supplemental water required. If the same site were planted with high maintenance turf grass (KL 0.9), however, even a 150,000 gallon cistern shows a remaining demand for over 60,000 gallons of supplemental water required. This case illustrates that, in a dry year, planting species and density (KL) creates a notable difference in the successful use of an active rainwater harvesting system. Charting the same planting areas (KL 0.55 and 0.9) on the sample design site for the wet year, 2003, rain is plentiful and no supplemental water is required regardless of planting type.

CONCLUSIONS

This study has generated an evaluative model, in the form of spreadsheets, which can be used in design by iterativeapplication of trial inputs. Although the model has been applied only to one site in northern Georgia, it can probably be applied elsewhere using different input data. The spreadsheets and charts demonstrate the limits of the physical feasibility of a rainwater harvesting system and can guide the design process toward practical choices. This model should be applied using locally specific precipitation and potential evapotranspiration data for a specific design proposal.

The following conclusions are supported by the study's results:

1) In the humid climate of northern Georgia, the question of whether a rainwater harvesting system is physically feasible does not have a fixed yes-or-no answer, rather the answer is specific to each project design. Design variables that could be manipulated in any one project to increase physical feasibility include catchment size, irrigation area, landscape planting composition (and thus landscape coefficient, KL), and cistern size.

2) As roof catchment area increases, quantity of harvested water increases and the feasibility to support the landscape plantings increases up to the limit where all water that the landscape can take has been supplied.

3) As cistern size increases, feasibility increases up to a limit, which can be found by applying this model.

4) Various types and densities of vegetation, along with microclimate, can alter feasibility and can be modeled using these spreadsheets.

5) Size of planting area can be reduced or increased in this model to design for optimal water use efficiency.

As a result of what has been learned, the questions stated in the introduction are reviewed and reformulated.

1) 'Is rainfall plentiful enough that no additional irrigation is required?' This paper demonstrates through the Irrigation Requirement Results displayed in Table 1, that in a dry year irrigation is clearly called for, while in a wet year there is no need for irrigation. This question is now reformulated as: since rainfall is not plentiful enough in a dry year, how will the required irrigation be provided? Rainwater harvesting could provide the solution.

2) 'When is it practical to make a water harvesting system 'active' by adding a cistern?' This question is now reformulated as: if an active rainwater harvesting system is put in place to accommodate irrigation needs in a dry year, how will the harvested water be put to use in a wet year? Should the cistern supply water for something in addition to irrigation? The Coverdell Center at The University of Georgia provides a perfect reference case in that the cistern provides water for the cooling tower, for toilet flushing, and for irrigation. An active rainwater harvesting system supplying multiple needs is desirable.

3) 'If irrigation is required only for plant establishment, does it make sense to install cisterns for the long term?' This paper does not attempt to study plant establishment, however it does make a case for the feasibility of installing cisterns for the long term for irrigation during dry years.

4) 'Must planting designs be adjusted to accommodate available quantities of harvested water?' This paper does determine that planting designs can be adjusted, as one of several factors that can be varied, in determining a design. It is also possible that roof catchment areas can be increased to increase quantity of harvested water available.

5) 'Should cisterns serve the dual purpose of irrigation and stormwater detention?' It is not the intention of this paper to examine stormwater management. However, it should be noted that the Whitehead Research facility at Emory is a case where this has been done.

6) 'For a given irrigated landscape planting area, what is the optimal catchment area to achieve valuable water conservation?' Although a simple example was looked at in the current model, to arrive at an optimal ratio of catchment area to irrigation area requires further study.

In conclusion, a spreadsheet model has been created that can be used to answer questions in future applications on specific sites. Using the model, factors can be manipulated in design to find the most feasible combination of catchment area, planting area, planting type (landscape coefficient, KL), and cistern storage capacity.

Further refinements of this spreadsheet model in future studies would contribute valuable information. Among the possibilities for future studies are:

- Expanding the model to include multiple uses for harvested water
- Expanding the model to include stormwater management.
- A complementary study on the economic feasibility of rainwater harvesting systems in the southeast.
- A comparable study using this model on different sample sites.
- Tracking the process of employing the spreadsheet model as a tool to explore specific design options.

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